



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Evaluation of the implementation of occupational health, safety, and environment management systems in higher education laboratories

Laboratory researchers and students may expose to hazardous and toxic chemicals. Implementation of the Occupational Health, Safety, and Environment Management System (OHSEMS) has become a critical aspect in higher education. This study presents an overview of the evaluation of the implementation of the OHSEMS in higher education laboratories. The implementation of the OHSEMS is to prevent occupational accidents in the laboratory. The study design is a semiquantitative descriptive study. The aim of the study is to evaluate the implementation of the OHSEMS in higher education institution laboratories by evaluating the percentages of OHSEMS compliance in higher education laboratories. Five aspects are evaluated: occupational health, safety, and environment (OHSE) policy and commitment, planning, implementation, evaluation, and management review. The result shows that the average compliance with the OHSE policy and commitment aspect is 59.4% and for the planning, implementation, evaluation, and management review, the average compliance percentage are 33.0%, 65.3%, 26.0%, and 0.0%, respectively.

**By Fatma Lestari,
Anom Bowolaksono,
Sri Yuniatami,
Tia Retno Wulandari,
Saraswati Andani**

INTRODUCTION

The laboratory is a facilities for performing research and academic activities.

Fatma Lestari is affiliated with Occupational Health & Safety Department, Faculty of Public Health, Universitas Indonesia, Depok, West Java, Indonesia; Occupational Health, Safety, and Environmental Unit, Integrated Laboratory and Research Center (ILRC) Building 2nd floor Kampus Baru Universitas Indonesia, Depok, West Java 16424, Indonesia (e-mails: fatma@ui.ac.id; fatmalestari@icloud.com).

Anom Bowolaksono is affiliated with Department of Biology, Faculty of

The Occupational Safety and Health Administration (OSHA) has recorded several potential hazards in laboratories, including chemical, biological, physical, and safety hazards.¹

Laboratory activities, such as academic and research activities, expose laboratory employees to potential hazards and increase the risk of incidents. In 2013, a study by OSHA indicated that an academic laboratory is 11 times more dangerous than a laboratory in the industrial sector.²

Mathematics & Sciences, Universitas Indonesia, Depok, West Java, Indonesia; Occupational Health, Safety, and Environmental Unit, Integrated Laboratory and Research Center (ILRC) Building 2nd floor Kampus Baru Universitas Indonesia, Depok, West Java 16424, Indonesia.

Sri Yuniatami is affiliated with Occupational Health & Safety Department, Faculty of Public Health, Universitas Indonesia, Depok, West Java, Indonesia.

Fire and explosion incidents caused by the use of chemicals are among the incidents that may occur in academic laboratories. The U.S. Chemical Safety Board has recorded several fire and explosion cases in academic laboratories that resulted in serious injuries when performing experiments with methanol. One incident occurred on September 3, 2014, at Terry Lee Wells Discovery Museum, Reno, Nevada, which injured 13 people and most were children. Another case occurred

Tia Retno Wulandari is affiliated with Occupational Health & Safety Department, Faculty of Public Health, Universitas Indonesia, Depok, West Java, Indonesia.

Saraswati Andani is affiliated with Occupational Health, Safety, and Environmental Unit, Integrated Laboratory and Research Center (ILRC) Building 2nd floor Kampus Baru Universitas Indonesia, Depok, West Java 16424, Indonesia.

on October 20, 2014 in Raymond, Illinois, that injured three groups of students and one adult due to the fire caused by a methanol experiment.³ The National Fire Protection Association (NFPA) has recorded that from 2000 to 2015, tens of students experienced burns due to the experiments they performed in the lab.⁴ The NFPA also recorded several incidents, such as the one in 2006 where three students in Ohio were injured when the methanol they were using for an experiment exploded. Another incident happened in 2011, when four students in Minnesota were burnt by chemicals.⁴

Other incidents that may occur in laboratory are caused by biological hazards. In 1976, Pike stated there were at least 173 deaths were caused by infection in laboratories.⁵ A case from November 2003 was recorded in Singapore, when a microbiology post-graduate student became infected by a West Nile virus culture he was using, which was also contaminated by the SARS corona virus.⁵

Occupational accidents have occurred in universities in Indonesia, namely, laboratory (2015) and fire (2017) incidents. Those incidents created substantial negative effects, including negative financial negative effects because of damages to facilities, health effects in the form of morbidity (i.e., starting from mild to serious and even death), environmental effects (i.e., pollution), and degrading the image of the university.^{6–12} Therefore, to prevent incidents in laboratories, formulating and implementing a management system that manages risks to prevent or minimize incidents is necessary. The management system that manages risk in laboratories in the field of occupational health, prevention of occupational diseases, and protection of environment is called the Laboratory Occupational Health, Safety, and Environment Management System, or Laboratory OHSEMS. Laboratory OHSEMS involves all elements, including the management, staff, students, and work environment, that are integrated to achieve a laboratory that is a safe, efficient, and productive learning facility.^{13–18}

Higher education institutions have a commitment to implement the aspect

of occupational health, safety, and environment (OHSE) in all activities. To support this commitment, higher education institutions have guidelines and manuals regarding safety applicable to the activities performed in its vicinity. One set of safety guidelines outlines laboratory safety to decrease or prevent incidents in the laboratory.

Laboratories host complex activities that include activities related to various research and student activities. A laboratory may include workstations and be a facility for research that involves humans, microorganisms, plants, animals, and nanoparticles. A laboratory may also host activities that could trigger fires and explosions. Various hazards, such as chemical, biological, physical, and ergonomic hazards, also found in laboratories, increase the risk of incidents. Additionally, high-value strategic assets like human resources, facilities, and infrastructures require protection; hence, it is critical that the OHSEMS be formulated, implemented, and continually improved to achieve the best results possible. This study aims to evaluate the implementation of the OHSEMS in higher education institution laboratories by using the higher education institution OHSE implementation standard guideline (Table 1).

METHODS

This study was a semiquantitative descriptive study using direct observation, interviews, and document studies performed during the period of April–May 2016. The aim of this study was to understand the compliance with OHSEMS in each laboratory. More specifically, the compliance in five aspects of the OHSEMS: OHSE policy and commitment, planning, implementation, evaluation, and management review. The results of study the were compared with the laboratory OHSEMS standards that were divided into three categories of OHSEMS achievement in laboratory: >70%, 50–70%, and <50%.

The laboratory OHSEMS inspections were performed in 90 laboratories in seven faculties: Faculty A (Engineering), B (Science), C (Medicine), D,

Table 1. OHSEMS Compliance in Each Laboratory.

Laboratory Number	OHSEMS Compliance (%)
1	92
2	39
3	16
4	36
5	88
6	57
7	28
8	58
9	45
10	42
11	56
12	71
13	72
14	72
15	68
16	61
17	63
18	78
19	73
20	59
21	63
22	73
23	84
24	67
25	74
26	75
27	61
28	58
29	68
30	65
31	52
32	48
33	51
34	70
35	22
36	79
37	48
38	27
39	46
40	40
41	40
42	51
43	70
44	82
45	56
46	26
47	36
48	24
49	42
50	25
51	53
52	42
53	20

Table 1 (Continued)

Laboratory Number	OHSEMS Compliance (%)
54	67
55	71
56	35
57	66
58	49
59	43
60	53
61	52
62	55
63	53
64	57
65	51
66	41
67	44
68	41
69	67
70	60
71	60
72	64
73	67
74	54
75	60
76	60
77	35
78	29
79	43
80	38
81	42
82	59
83	43
84	43
85	59
86	74
87	55
88	58
89	44
90	57
Average OHSEMS compliance	54%

E, F, and G (Health). The informants interviewed were the head of laboratory, laboratory technicians, a laboratory technician assistant, and students. Two types of data were collected: primary and secondary data. The primary data collection was performed through direct observation by using a checklist on the implementation of laboratory OHSE management system implementation and collecting information from resource persons/informants on the evaluation of the higher education

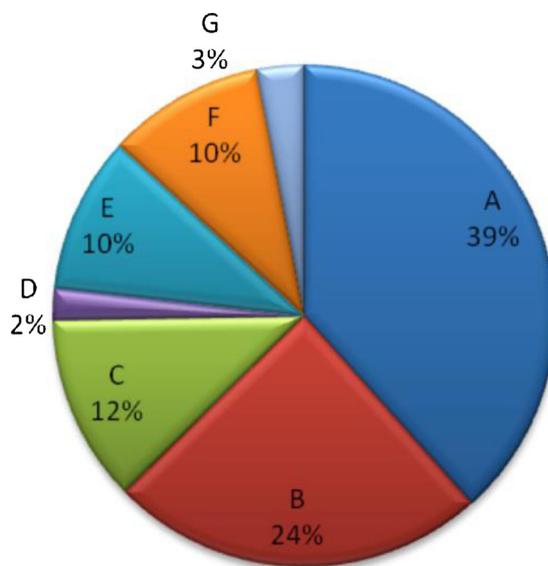


Figure 1. Diagram of the Distribution of the Number of Laboratories in Each Faculty A: Engineering, B: Science, C: Medicine, D, E, F & G: Health.

institution laboratory OHSE management system through interviews. The secondary data were collected to review the documents related to the laboratory OHSE management system implementation.

RESULTS AND DISCUSSION

The results of the evaluation on the OHSEMS in higher education institution laboratories is presented in the form of compliance with the OHSEMS in each laboratory and each aspect of the OHSEMS. Figure 1 presents the distribution data of the number of laboratories studied in each faculty. Figure 2 presents data on total compliance with the OHSEMS of each laboratory. Figure 3 presents the distribution of OHSEMS compliance. Figure 4 shows the compliance with each aspect of OHSEMS in each laboratory. Figure 5 presents the data on compliance with each OHSEMS aspect.

OHSE Policy and Commitment

The level of compliance for OHSE policies and commitment was 59.4%, that is, 54 laboratories have already implemented policies and commitments related to OHSEMS in laboratory. This result is supported by the formulation of OHSE policies,

commitments of all the laboratories, communication of the policies, and commitments to all laboratory users signed by the top management position responsible for the laboratory OHSEMS. This is aligned with previous study related to chemical safety and security in laboratory, that laboratory policy plays important role for OHSE implementation.¹⁸

Planning

The planning aspect comprises the following elements: (i) hazard identification, risk assessment, and determining control (HIRADC); (ii) legal and other requirements; and the availability of (iii) programs related to OHSE in laboratory. HIRADC is a stage that provides overall information on potential hazards, risk probability, and related controls of a laboratory area. The head of laboratory, laboratory technicians, and students must perform HIRADC and document the result before starting their experiment. After HIRADC is performed, legal and other requirements should simultaneously be considered when developing a work plan; then, each laboratory has a different work plan depending on its potential hazards to protect those who work in and are in contact with the laboratory.

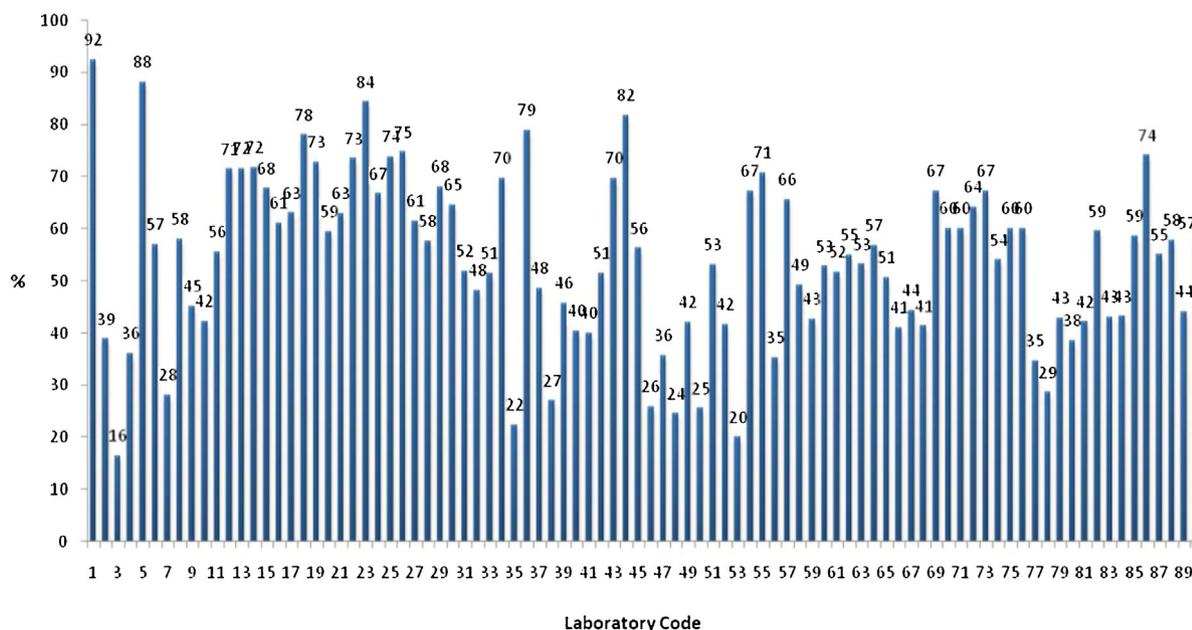


Figure 2. Chart on Total OHSEMS Compliance in Each Laboratory.

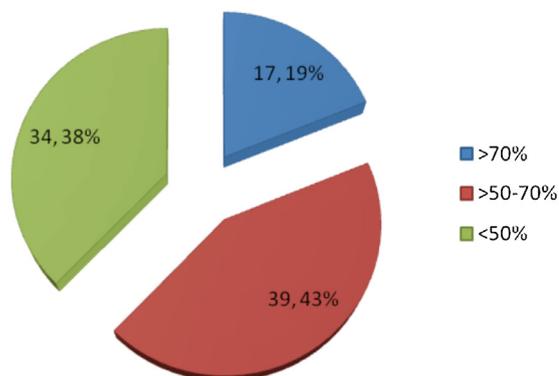


Figure 3. Distribution of OHSEMS Compliance in Laboratories.

The higher education institution at the study location complies with the planning aspect of 33%, that is, as many as 30 laboratories have performed OHSE planning in the laboratory. Improvement is required in the other 60 laboratories (57%) to implement planning, that is, disseminate the importance of creating the HIRADC, the standard for HIRADC document formulation, and the regulations owned by the institution related to the aspects of OHSE in laboratory.

Implementation

The implementation aspect comprises the availability of (i) resources, roles,

and responsibility, accountability, and authority; (ii) awareness improvement, competency improvement, and training; (iii) communication, participation, and consultation; (iv) documentation and document control; (v) operational control; and (vi) emergency situation preparation. The compliance with this aspect is 65.3%, or 59 laboratories have complied to this aspect.

The availability of human resources responsible for safety, health, and environment in the laboratories is identified in most laboratories in this higher education institution. The human resources are available at the faculty, department, and laboratory levels. The availability of human resources

guarantees an optimal chance of implementation of OHSE in the laboratory.¹⁸

Improved awareness, competency and training includes training associated with specific potential hazards in each laboratory, such as chemical hazards, bio risk management, radiation safety, and training on how to develop documents related to laboratory OHSE. This training can be online or face-to-face. Most laboratories in this higher education institution have complied with this element.¹⁸

The element of communication, participation, and consultation is the element that requires communication as part of laboratory participation, internally and externally, in a laboratory committee that discusses all aspects related to OHSE in laboratories. This objective of this element is to optimize the performance of OHSE. Most laboratories in this higher education institution must implement this element.

In terms of OHSEMS documentation, most laboratories in this higher education institution have an OHSE guideline, standard operating procedures (SOPs), and OHSE work instructions that are easily accessible to the laboratory users to guarantee an effective planning, operation, and control process in OHSE risk management.

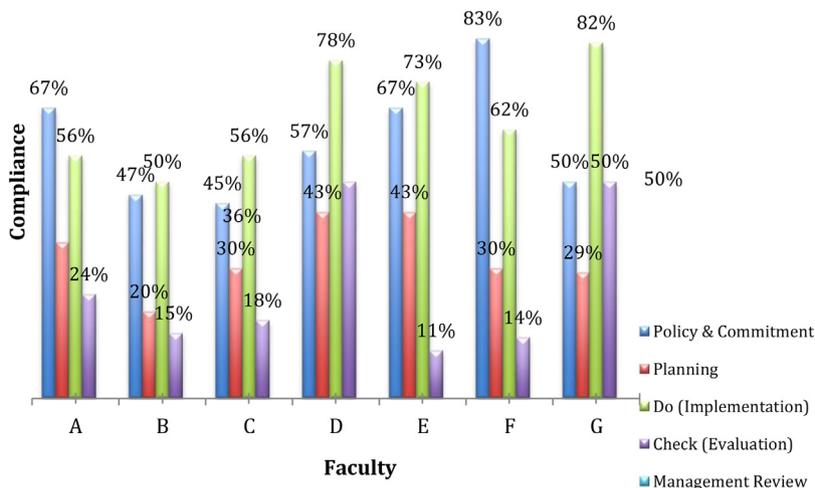


Figure 4. Compliance to Laboratory OHSEMS Aspects of Each Faculty.

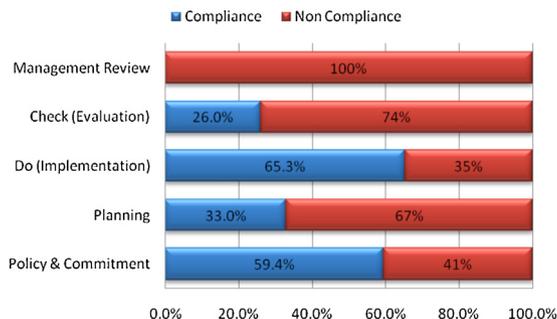


Figure 5. Compliance to the Aspects of Laboratory OHSEMS.

The operational control element, such as for the facilities and infrastructure of the laboratory, has complied with the standards applicable in this higher education institution, for example, the availability of safety washer and eye washer for first aid in the event of an occupational accident in the laboratory. The chemicals are stored according to their type. The flammable and corrosive chemicals are stored in a cabinet specifically made for flammable and corrosive chemicals according to the standard applicable in the higher education institution. The hazard communication is performed by posting safety signs about topics such as the use of personal protective equipment and prohibition to eat and drink, and hazard signs on all laboratory equipment. To handle electricity hazards, all electric devices and instruments in the laboratories are already grounded to prevent electrocution and fire.

The preparedness and emergency response facilities available in laboratories include fire extinguishers for fire emergency response procedures. Well-maintained spill kits are also available to handle chemical spills. The waste produced by laboratories has already been segregated, labeled, and stored according to type and then disposed of by a third party to prevent environmental pollution in the higher education institution area. Similar best practices have been previously observed in chemical safety and security baseline study.¹⁸

Evaluation

The compliance with the laboratory OHSE evaluation aspect is 26%. This aspect in the OHSE evaluation comprises three elements: (i) performance measurement and monitoring; (ii) incident investigation, improvement action, and prevention; and (iii)

laboratory internal audit. The laboratories in the higher education institution perform performance measurements on the compliance with OHSE in each laboratory and evaluate the results to improve performance in OHSE. Incident investigation and internal audit activities are performed based on the incident reporting and investigation SOPs of the higher education OHSE Technical Implementing Unit. The results of the investigation are reported to the unit and documented for evaluation and to comply with the regulation.

Management Review

The compliance with the OHSE management review aspect in the higher education institution laboratories is 0%, that is, no laboratory performs management reviews. Overall, each laboratory has not applied the OHSEMS review due to the insufficient resources to manage OHSE in laboratories. The higher education institution should consider performing management reviews to ensure the OHSEMS has been implemented according to plan; then, if a deviation is observed, action can be immediately to make improvements.

CONCLUSION

The OHSEMS has been implemented in all laboratories in this higher education institution. As many as 15 laboratories (17%) have complied with more than 70% of the OHSEMS standards, and 35 laboratories (39%) have complied with 50%–70% of the standards. A strong policy and commitment aspect are already available in all laboratories in this higher education institution. Notably, several aspects should be improved, including the planning aspect, specifically the HIRADC element, and all elements of evaluation and management review.

REFERENCES

- Occupational Safety and Health Administration (OSHA). *Laboratory Safety Guidance 3404-11R*. 2011. www.osha.gov, accessed 03/01/2016 at 18.00 WIB.

2. Evans, Jon. Safety first? *R. Soc. Chem. J.* **2014** <http://www.rsc.org/chemistryworld/2014/05/safety-first>, accessed 03/02/2016 at 15.00 WIB.
3. U.S. Chemical Safety Boards. *Key Lessons for Preventing Incidents from Flammable Chemicals in Educational Demonstrations in Wake of Several Serious Methanol Accidents that Injured Children and Adults*. 2014. Oktober 30, 2014. <http://www.csb.gov>, accessed 03/02/2016 at 12.00 WIB.
4. Minister, Andrew. Unsafe science. *NFPA J.* **2015** <http://www.nfpa.org/newsandpublications/nfpa-journal/2015/september-october2015/features/unsafe-science>, accessed 03/02/2016 at 12.30 WIB.
5. Singh, Kamaljit. Laboratory-acquired infections. *Oxford J.* **2009** <http://cid.oxfordjournals.org/content/49/1/142.full>, accessed on 03/02/2016 at 12.35 WIB.
6. Belli, S.; Combo, P.; De Santis, M.; Grignoli, M.; Sasco, A. J. *Scand. J. Work Environ. Health*, **1992**, *18*, 64.
7. Boxer, P. A.; Burnett, C. M.; Swanson, N. J. *Occup. Environ. Med.* **1995**, *37*.
8. Dement, J. M.; Cromer, J. R. *Appl. Occup. Environ. Hyg.* **1992**, *7*, 120.
9. Walrath, J.; Li, F. P.; Hoar, S. K.; Mead, M. W.; Fraumeni, J. F. *Am. J. Public Health*, **1985**, *75*.
10. NIOSH (National Institute for Occupational Safety and Health). *A Cohort Mortality Study of Chemical Laboratory Workers at Department of Energy Nuclear Plants*. 2008. (Published online) <http://www.cdc.gov/niosh/oerp/pdfs/OERP-INFO-a.pdf>.
11. UCSC. *University of California Santa Cruz Fire*. 2002. (Published online) <http://ehs.ucsc.edu/emergency/pubs/sinshfire2.htm>.
12. Safety in Academic Chemistry Laboratories. *7th ed. Accident Prevention for College and University Students*, vol. 1, 7th ed.: American Chemical Society: Washington, DC, 2003; <http://portal.acs.org/portal/Navigate?nodeid=2230>
13. American Chemical Society (ACS) (Ed.). *Safety Audit/inspection Manual*. American Chemical Society: Washington, DC, 2000, <http://portal.acs.org/portal/Navigate?nodeid=2230>.
14. *Security Vulnerability Checklist for Academic and Small Chemical Laboratory Facilities*, American Chemical Society (ACS), Ed. http://portal.acs.org/preview/PublicWebSite/about/governance/committees/chemicalsafety/publications/WPCP_012339
15. Chemical Laboratory Safety and Security. In Lisa, M.; Masciangioli, T. (Eds.), *A Guide to Prudent Chemical Management*. The National Academies Press, 2010, <http://www.qitepscience.org/resources/Chemica.pdf>.
16. Barbara, L. F. *Chem. Health Saf.* **2004**, *11*, 6.
17. DeWinkle, G. M.; Rosbach, M. L. *Chem. Health Saf.* **2000**, *7*, 26.
18. Baseline Survey on The Implementation of Laboratory Chemical Safety. Health and security within health faculties laboratories at Universitas Indonesia. *J. Chem. Health Saf.* **2016**, *23*(4), 38–43, <http://dx.doi.org/10.1016/j.jchas.2015.11.002>.